COMSOL CONFERENCE ROTTERDAM 2013

MODELING OF A MAGNETOCALORIC SYSTEM FOR ELECTRIC VEHICLE

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SEVENTH FRAMEWORK PROGRAMME

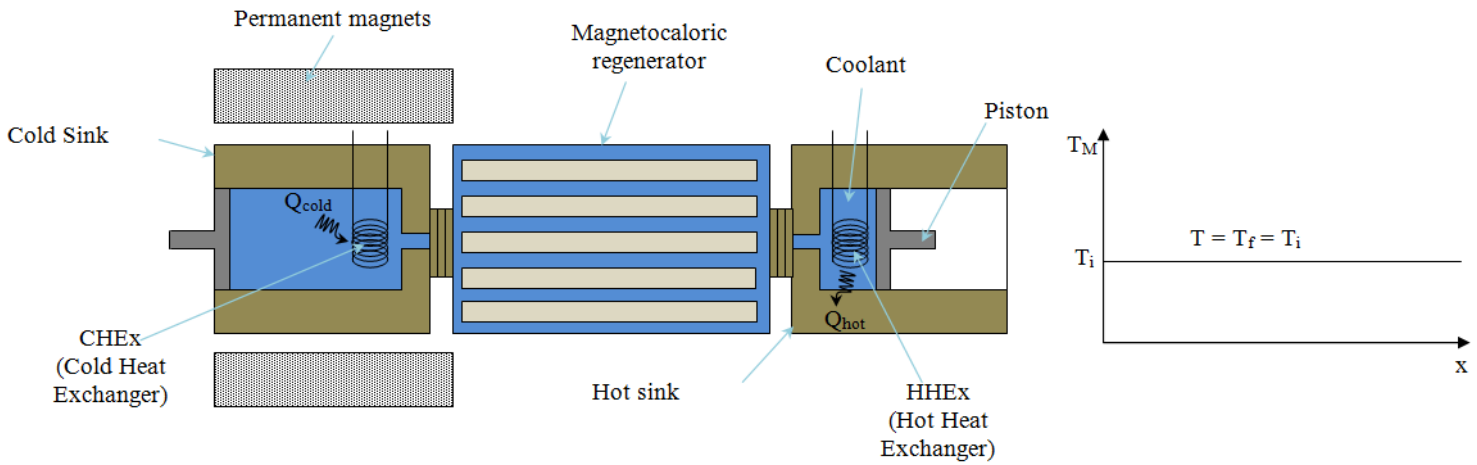
ICE PROJECT: OBJECTIVES

- Development of an efficient air-conditioning and heating system based on Magneto-Caloric heat pump
- New system architecture to fulfill the thermal comfort and energy requirements of a FEV

Heating power: 5 kW
Cooling power: 3 kW
Temperature span:-7°C,+50°C
COP ≥ 3

MAGNETOCALORIC HEAT PUMP

- Based on Magneto-Caloric Effect (MCE)
- MCE: temperature changing of a magneto-caloric material exposed to a changing magnetic field
- Active Magnetic Regenerator (AMR)



MAGNETOCALORIC HEAT PUMP

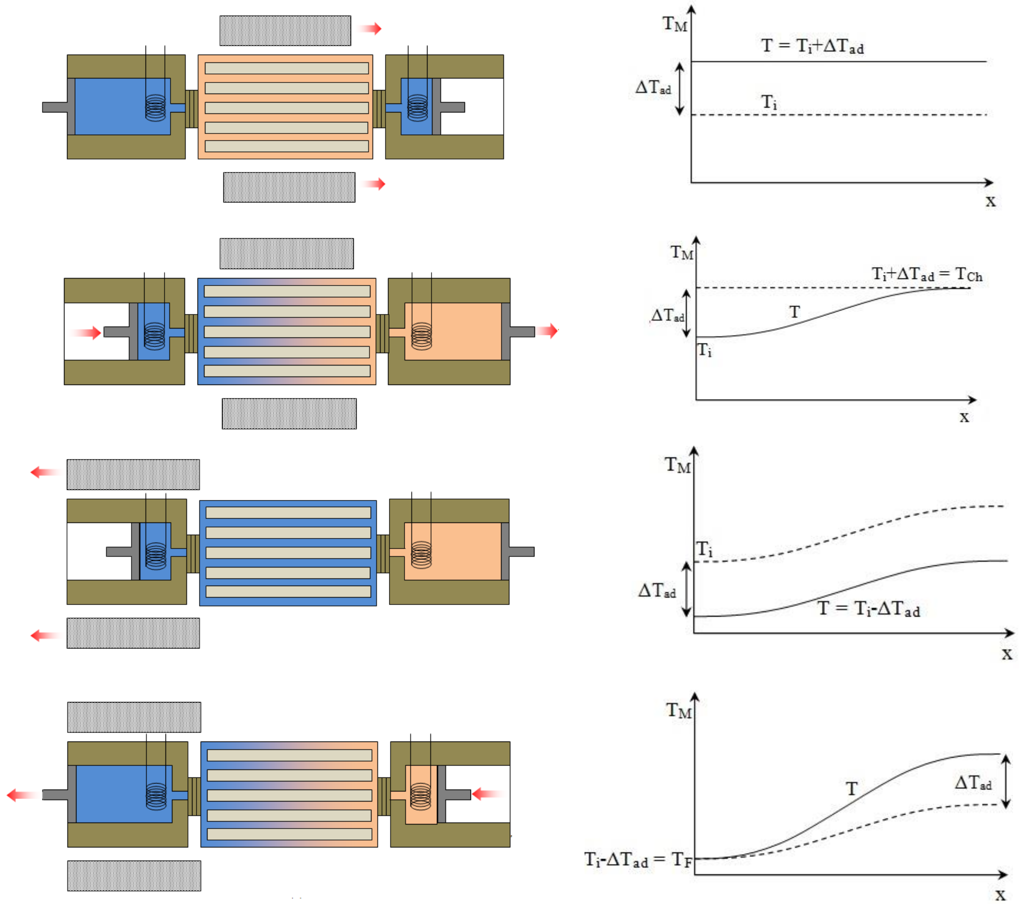
- Active Magnetic Regenerator cycle(AMR cycle)

(1)
Adiabatic magnetization

(2)
Isofield cooling
(Maximal magnetic field)

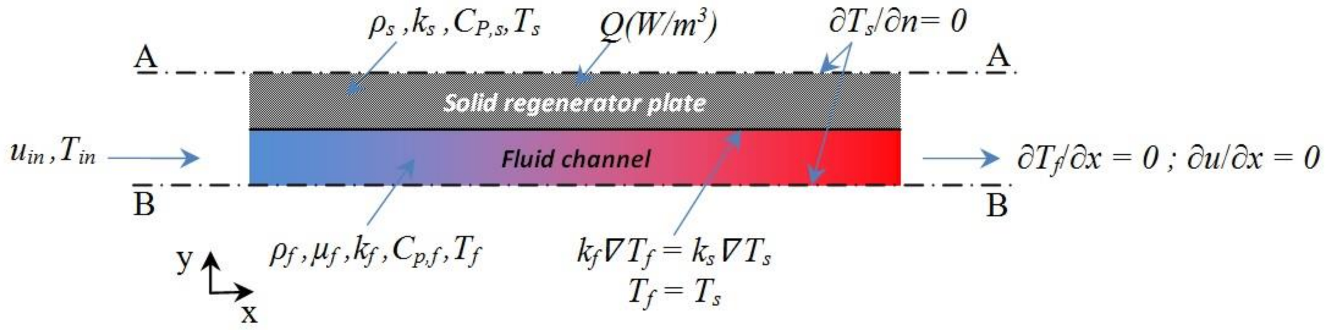
(3)
Adiabatic demagnetization

(4)
Isofield heating
(Minimal magnetic field)



MODELING OF MAGNETOCALORIC HEAT PUMP

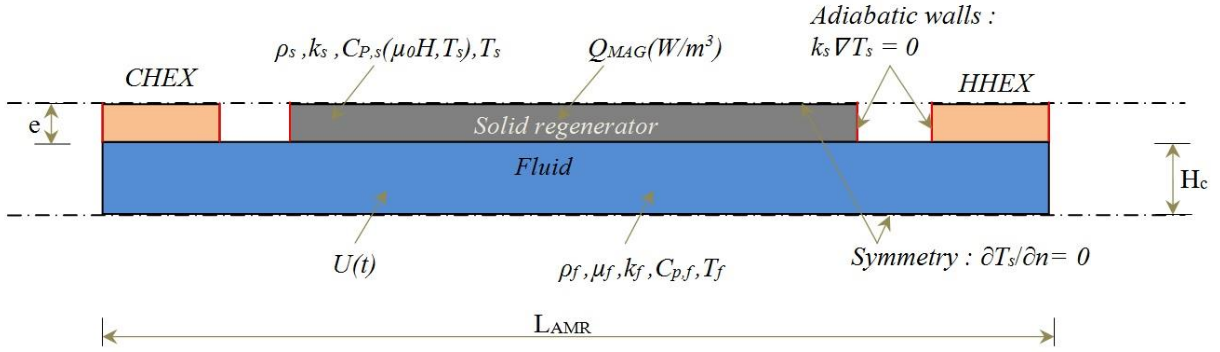
- Model of fluid flow and heat transfer in Minichannel



Mass conservation equation	$\nabla \cdot \vec{u} = 0$
Momentum equation	$\rho_f (\vec{u} \cdot \nabla)\vec{u} = -\nabla p + \mu_f \nabla^2 \vec{u}$
Energy equation for fluid domain	$\rho_f C_{p,f} \left(\vec{u} \cdot \nabla T_f\right) = k_f \nabla^2 T_f$
Energy equation for solid domain	$k_s \nabla^2 T_s + Q_0 = 0$
Equation for heat transfer coefficient	$h = \dfrac{q_{wall}}{T_{wall} - T_f}$

MODELING OF MAGNETOCALORIC HEAT PUMP

- Physical model of AMR cycle



Energy equation for fluid
$$\rho_f C_{p,f}\left(\frac{\partial T_f}{\partial t} + (\vec{u}\cdot\nabla)T_f\right) = \nabla\cdot\left(k_f \nabla T_f\right) - \dot{Q}_{TT}$$

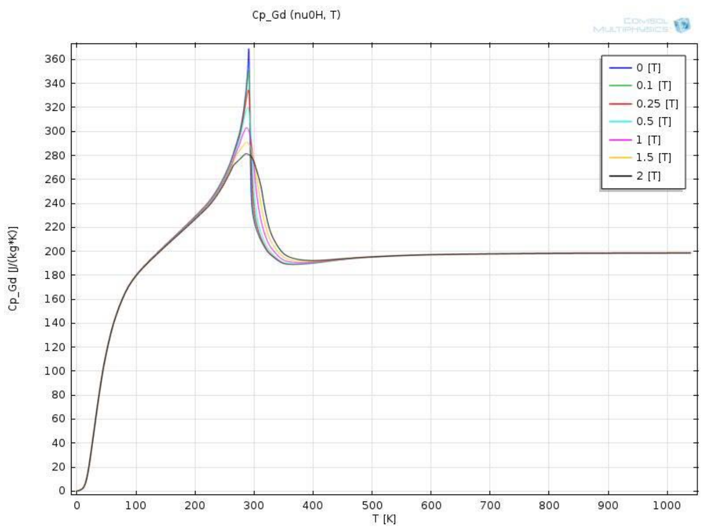
Energy equation for solid
$$\rho_s C_{p,s}\frac{\partial T_s}{\partial t} = \nabla\cdot(k_s \nabla T_s) + \dot{Q}_{MAG} + \dot{Q}_{TT}$$

Equation of MCE source term
$$\dot{Q}_{MCE} = \rho_s C_{P,s}\left(\frac{\partial T_{ad}}{\partial H}\frac{dH}{dt} + \frac{\partial T_{ad}}{\partial T_s}\frac{dT_s}{dt}\right)$$

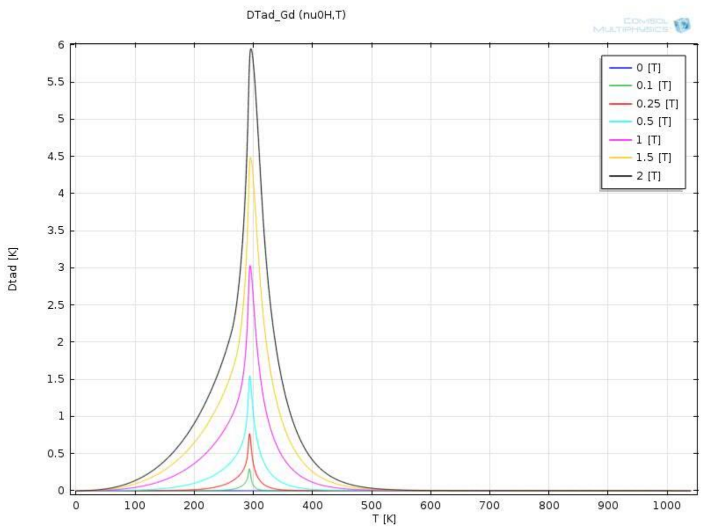
Equation of heat transfer between fluid and solid as source term
$$\dot{Q}_{TT} = h\beta\left(T_s - T_f\right)_{Int:f/s}$$

MODELING OF MAGNETOCALORIC HEAT PUMP

- Interpolation of Cp and ΔTad of Gadolinium



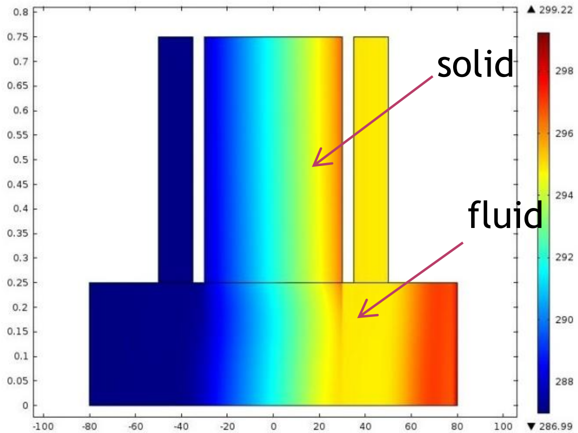
Variation of Cp with temperature, for $0 \le \mu0H \le 2$ T



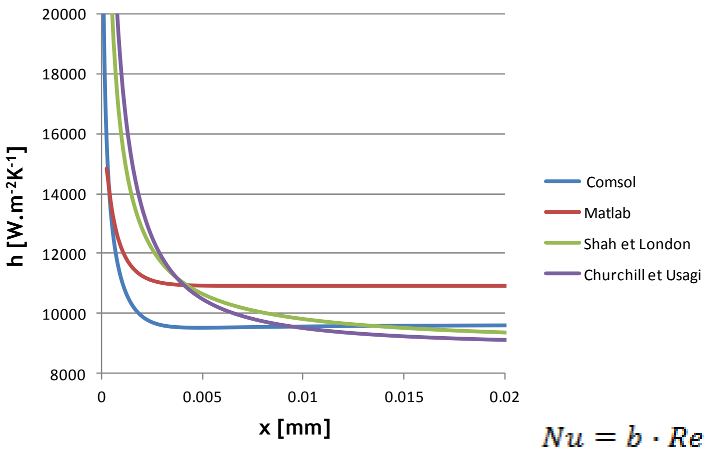
Variation of ΔTad with temperature, for $0 \le \mu0H \le 2$ T

$$\dot{Q}_{MCE} = \rho_{Gd} Cp_{Gd}\left(T, \mu_0 H(t)\right) \frac{\Delta Tad_{Gd}\left(T, \mu_0 H(t+dt)\right) - \Delta Tad_{Gd}\left(T, \mu_0 H(t)\right)}{dt}$$

RESULTS AND CONCLUSION



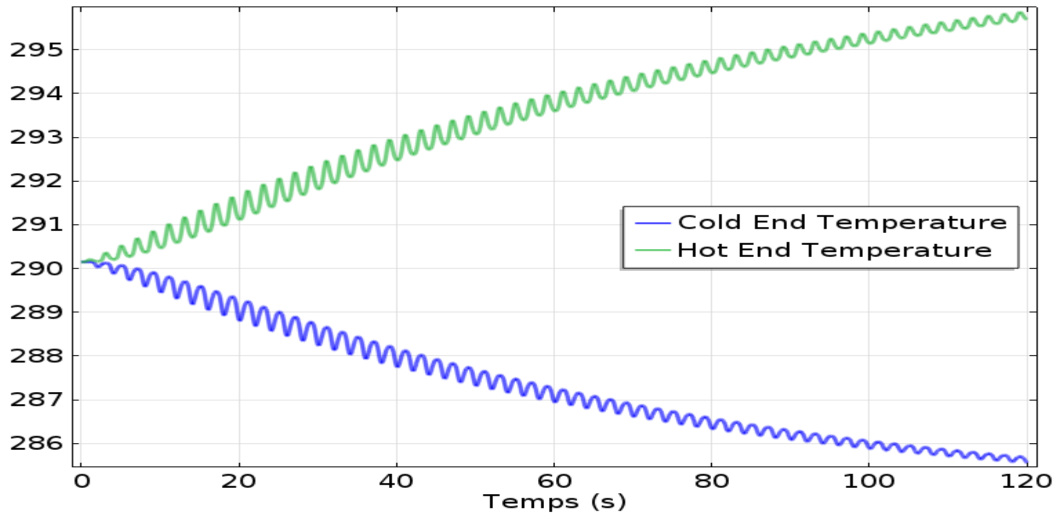
Temperature field



Heat transfer coefficient

$$Nu = b \cdot Re^m \cdot Pr^n$$

$$Nu = \frac{hD}{k_f}$$



Hot end and cold end temperatures of the cycle

RESULTS AND CONCLUSION

Contributions

- A different and acurate approach to calculate de QMCE
- An accurate determination of heat transfer coefficient

ENCOUNTERED PROBLEMS

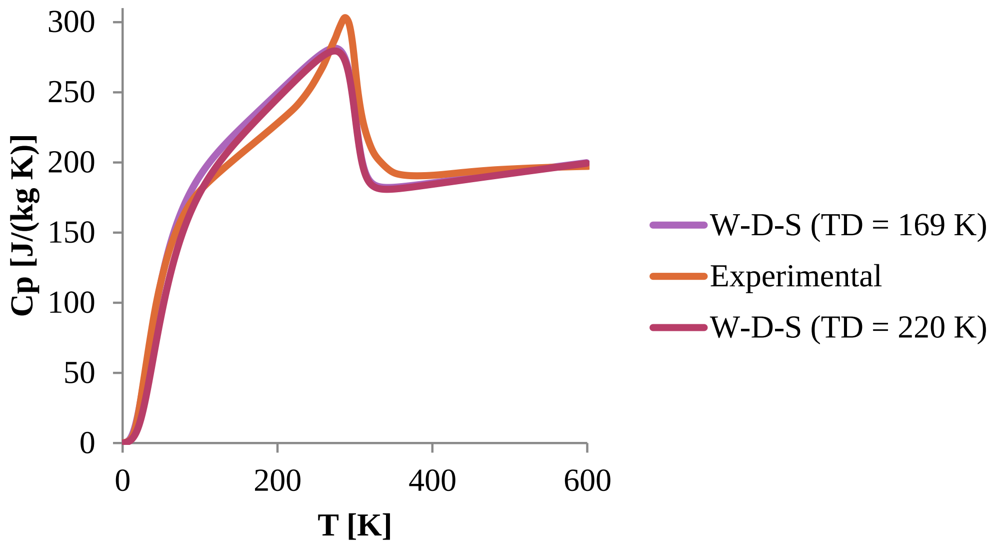
- Implementation of Q_{MCE}
- Requirement of high quantity of memory

FUTURE WORK

- Analyse the surface rugosity influence on the fluid flow and heat transfer in microchannels.
- Analyse the influence of the dimensions of the system (plate thickness, channel height) on the heat transfer quantities.

- THANKYOU!

$\mu_0 H = 1$ [T]



$\mu_0 H = 0$ [T]